The City College
City University of New York

Final Report

Investigation of Models for Large Scale

Meteorological Prediction Experiments

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I. Introduction

Research has been carried out by the City College group in association with the Goddard Institute for Space Studies (GISS) under grant NGR 33-013-086 since October 1973. Prior to that time this research activity was located at New York University under the same principal investigator. During all these years a close and fruitful relationship has been maintained between GISS and the university group, thanks to the cooperation and assistance of Robert Jastrow, James Hansen, and their associates at GISS.

Most of the effort of the project has been devoted to long-range numerical prediction and climate simulation experiments with various global atmospheric general circulation models developed at GISS. Over the years, this research has resulted in a number of publications and technical reports, in addition to the regular annual "final" reports of the project. This final final report consists mainly of a chronological listing of the titles of all publications and technical reports already distributed, together with an account of the most recent research performed under the grant during the past half year.

Two graduate students employed on the project (Charles Cohen and Peter Wu) completed their studies at The City College during the past summer, leaving one graduate assistant, Dominic Fong, to complete his master's program under the aegis of the grant. Several reports on a series of perpetual January climate simulations with the GISS coarse mesh climate model, that were completed this year by Cohen, Wu, and Spar, have already been distributed, and are listed below among the technical reports of the project. Subsequently, Mr. Fong has carried out a set of perpetual July climate simulations with the same model, results of which are described in the following report.

II. (A) Publications

Spar, J., 1973 (a): Some effects of surface anomalies in a global general circulation model. Mon.Wea.Rev., 101, 91-100.

______________, 1973 (b): Transequatorial effects of sea-surface temperature anomalies in a global general circulation model. Mon.Wea.Rev., 101, 554-563.

______________, 1973 (c): Supplementary notes on sea-surface temperature anomalies and model-generated meteorological histories. Mon.Wea.Rev., 101, 767-773.

Spar, J. and R. Atlas, 1975: Atmospheric response to variations in sea-surface temperature. J.Appl.Meteor., 14, 1235-1245.

______________, R. Atlas, and E. Kuo, 1976: Monthly mean forecast experiments with the GISS model. Mon.Wea.Rev., 104, 1215-1241.

Spar, J., 1977 (a): A summary of monthly mean simulation experiments with the GISS model. Paper No. 58, pp. 323-327, NASA Conf. Publ. 2029. Third NASA Weather and Climate Program Science Review, NASA Goddard Space Flight Center, Greenbelt, Md.

______________, 1977 (b): Monthly mean forecast experiments with the GISS model: correction. Mon.Wea.Rev., 105, 535-539.

Spar, J., J. J. Notario and W. J. Quirk, 1978: An initial state perturbation experiment with the GISS model. Mon.Wea.Rev., 106, 89-100.

Spar, J. and R. Lutz, 1979: Simulations of the monthly mean atmosphere for February 1976 with the GISS model. Mon.Wea.Rev., 107, 181-192.

Spar, J., 1979: Prediction Experiments with a coarse-mesh global model. Proc. Fourth Annual Climate Diagnostics Workshop, Madison, Wisconsin, October 16-18, 1979. pp. 413-423. U.S. Department of Commerce. NOAA.

Christidis Z.D. and J. Spar, 1981: Spherical harmonic analysis of a model-generated climatology. Mon.Wea.Rev., 109, 215-229.

(B) Technical Reports

Spar, J., 1976: A synoptic review of some results from the DST-5 experiment.

Johnson, W. T., 1977: The determination of surface albedo from meteorological satellites.

Lutz, R. J., 1978: Experiments in monthly mean simulation of the atmosphere with a coarse-mesh general circulation model.

Notario, J. J., 1978: The influence of random initial state errors on monthly mean simulations with a coarse-resolution atmospheric model.

Spar, J., R. Klugman, J. R. Lutz, and J. J. Notario, 1978: Monthly mean simulation experiments with a coarse-mesh global atmospheric model.

Klugman, R., 1978: The influence of initial conditions on monthly mean simulations with a global atmospheric model.

Spar, J. and R. Klugman, 1979: Note on decay of predictability in forecast experiments with the GISS climate model.

_______, _________, and J. Notario, 1979: Effects of horizontal and vertical resolution in climate model forecast experiments.

Christidis, Z. and J. Spar, 1979: Spherical harmonic analysis for verification of a global atmospheric model.

Filadelfo, R., 1979: The effect of sea surface temperature anomalies on monthly mean simulations with a coarse mesh global general circulation model.

Christidis, Z., 1980: Spherical harmonic analysis of a synoptic climatology generated with a global general circulation model.

Dennis, M. and J. Spar, 1980 (a): Interim report on response of the GISS climate model to sea-surface temperature anomalies.

______ and ________________, 1980 (b): Eigenvalue analysis of some observed and model-generated climatological fields.

Spar, J., C. Cohen, and P. Wu, 1981: Do initial conditions matter? A comparison of model climatologies generated from different initial states.

Cohen, C., 1981 (a): The effect of surface boundary conditions on the climate generated by a coarse-mesh general circulation model.

______________, 1981 (b): The effect of zonal gradients of sea surface temperature on the Indian Ocean winter monsoon.

Spar, J., C. Cohen and P. Wu, 1981 (a): The thermal influence of continents on a model-generated January climate.

_____, ______, and _____________, 1981 (b): Summary of results of January climate simulations with the GISS coarse-mesh model.

Spar, J. and C. Cohen, 1981: Some effects of topography, soil moisture, and sea-surface temperature on continental precipitation as computed with the GISS coarse mesh climate model, (Presented at Sixth Climate Diagnostics Workshop, Lamont-Doherty Geological Observatory Palisades, N.Y., 15 October 1981.)

__________ and ___________, 1981: Effects of surface boundary conditions on continental precipitation computed with the GISS climate model. (To be published in Proceedings of the Sixth Climate Diagnostics Workshop.)

Wu, P., 1981: The influence of initial and surface boundary conditions on a model-generated January climatology.

III. Perpetual July climate simulations

Following completion of the perpetual January climate calculations (Cohen, 1981; Wu, 1981) with the GISS coarse mesh climate model (Hansen et al., 1980), the same model was used to generate three climate simulations for the month of July. In these runs, with the solar declination fixed at the value for July 15, the model was initialized with a dry, isothermal, homogenous state of rest, and allowed to "spin up" and run continuously for 25 (or 20) simulated months. The first 5 months of each run were then discarded, and ensemble mean July conditions, with standard deviations, were computed from the last 20 (or 15) monthly means of each series. (In one case the model was run for only 20 months, and the ensemble mean was computed from the last 15 months of the series.)

The first run (referred to here as run "5") was based on the "complete" model, with the ground moisture and variable surface albedo included, as in the complete January simulation (loc.cit.). A comparison of the results of this run with the observed global July climatology, as discussed below, provides further information on the credibility of the model's climate simulation.

In the second run with the July model, the surface albedo of all continents was fixed at 0.14, but all other conditions were exactly the same as in the complete run. The constant albedo calculation, designated as run "6", was performed in order to assess the influence of variable continental surface albedo, particularly on the rate of precipitation over the continents, as revealed by the difference between run 6 and run 5. (This question had not been completely resolved by the perpetual January experiment.)

Finally, in order to evaluate the influence of soil moisture on continental precipitation, the perpetual July run was repeated with zero water storage capacity on the continents, all other conditions being the same as in run 5. The results of this last run, which is referred to as run "7", were then subtracted from those of run 5 to determine the effects of the model soil moisture evaporation. (The dry case, run 7, was based on a 20-month run and a 15-month ensemble mean.)

A. Complete model July simulation (run 5)

Figures 1, 2, 3, and 4 illustrate, respectively the 500 mb geopotential heights, sea-level pressures, 1000 - 850 mb layer temperatures, and mean daily precipitation generated by the model for the month of July, while in figures 5, 6, and 7 are shown, respectively, the observed July climatological fields of 500 mb geopotential height, sea-level pressure, and 850 mb temperature.

From figures 1 and 5, it can be seen that the model, like the real atmosphere, generates a stronger zonal circulation at 500 mb in the Southern (winter) Hemisphere than in the Northern (summer) Hemisphere, and approximately the correct meridional slope of the 500 mb surface. However, the model-generated contour pattern in the Northern Hemisphere is unrealistic, being much too cellular and not reflecting adequately the weak zonal flow observed there.

At sea level (figs. 2 and 6), on the other hand, the pressure field is simulated more realistically north of the Equator than in the Southern Hemisphere, with the oceanic highs and continental lows of the summer hemisphere in about the correct locations. However, south of the Equator, not only is the pressure unrealistically high on the Antarctic continent, but the zonal pressure gradient north of

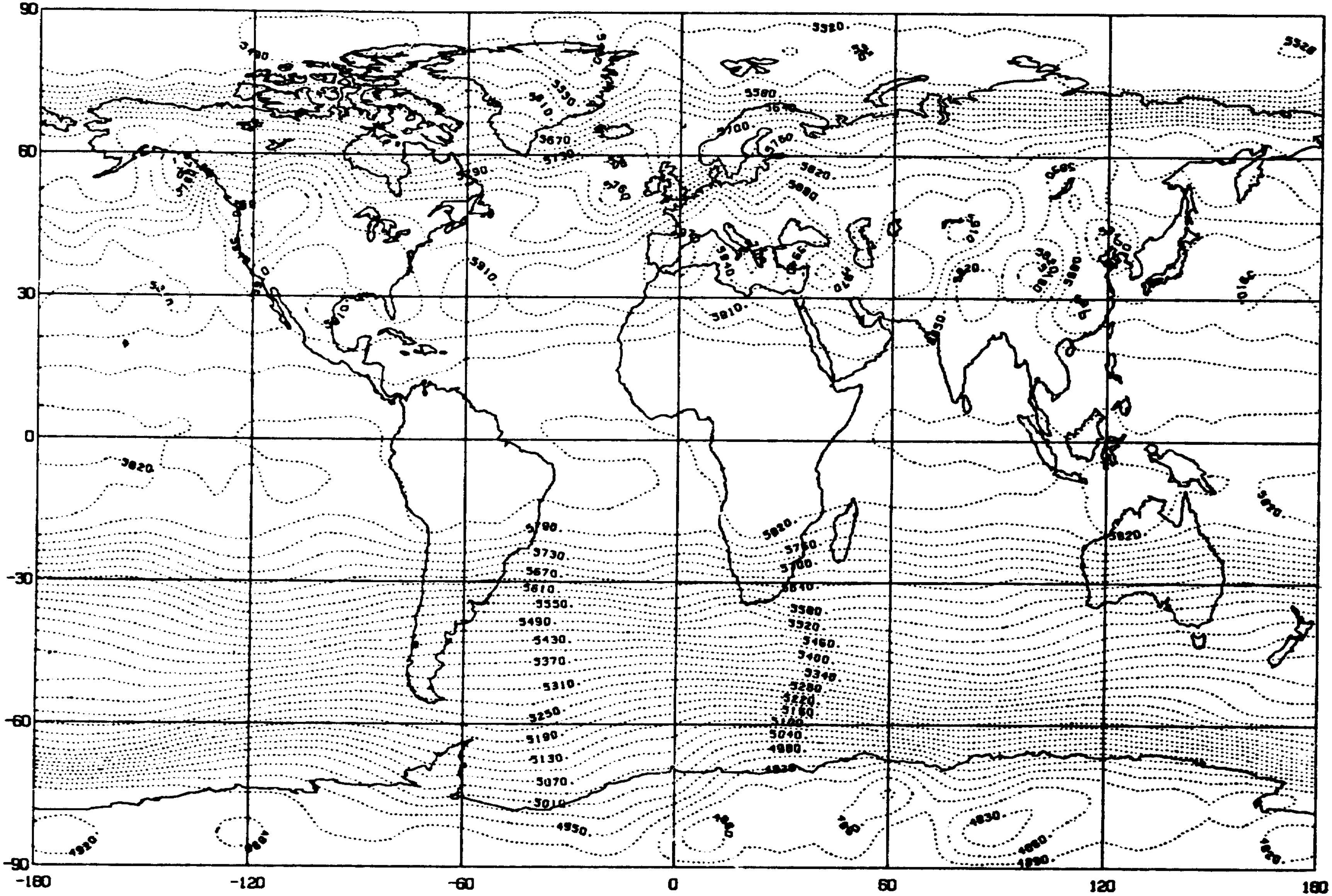

Fig. 1

MEAN 500MB HEIGHTS. IN METERS

THE AVERAGE OF THE LAST 20 MONTHS OF RUN 05L

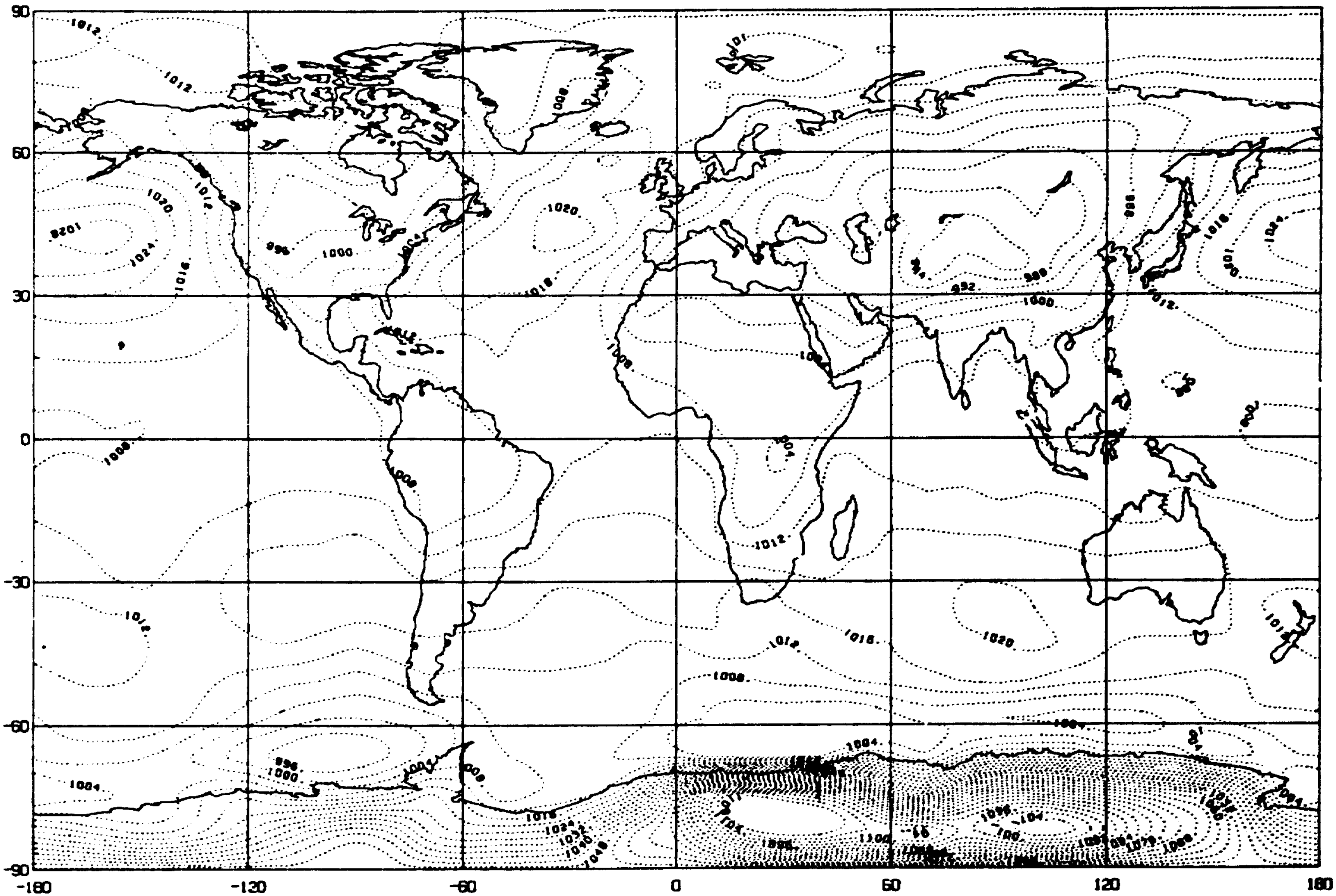

Fig. 2

MEAN SEA LEVEL PRESSURE, IN MB

THE AVERAGE OF THE LAST 20 MONTHS OF RUN 05L

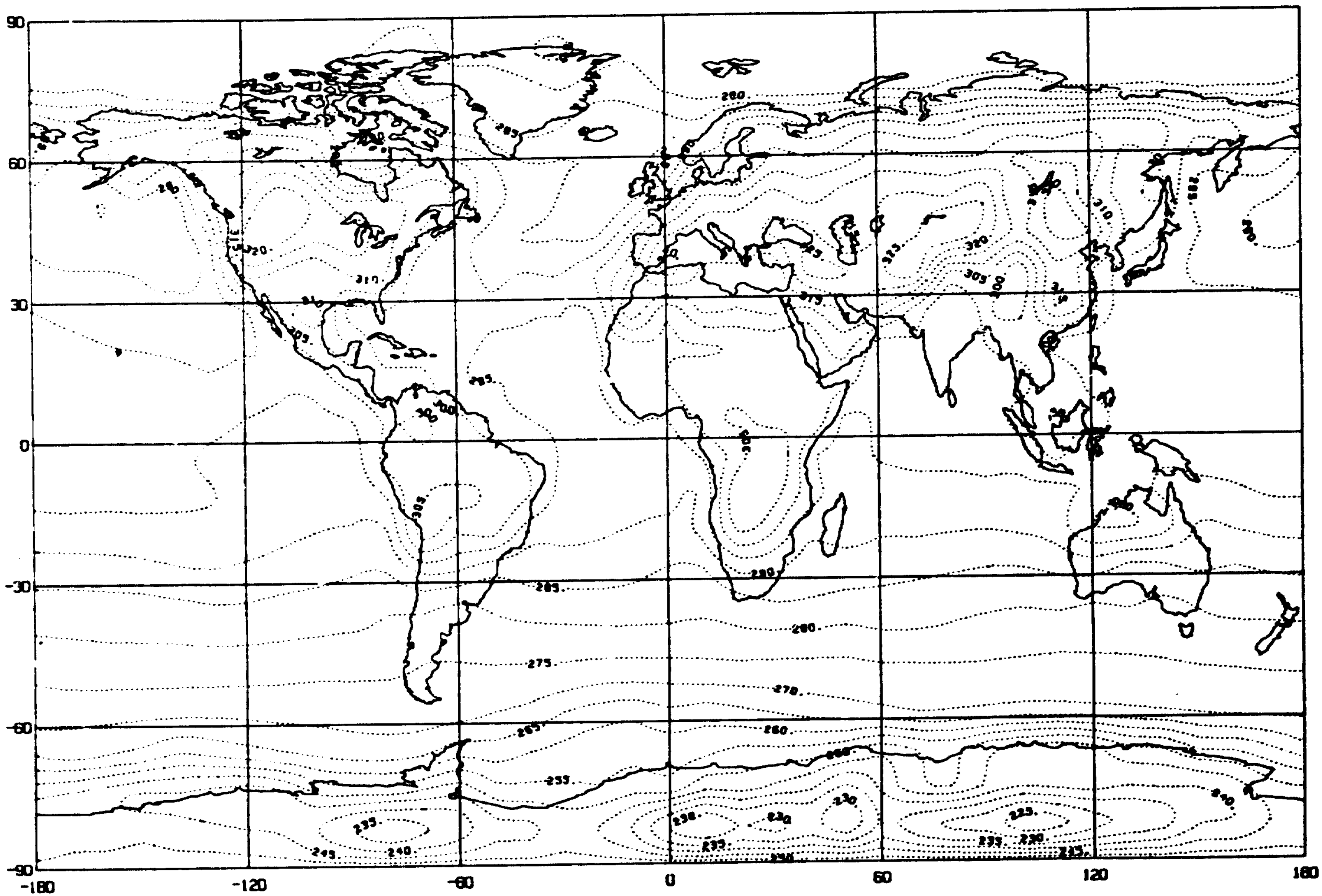

Fig. 3 MEAN THICKNESS TEMPERATURE FOR 1000-850MB LAYER. IN DEG K

THE AVERAGE OF THE LAST 20 MONTHS OF RUN 05L

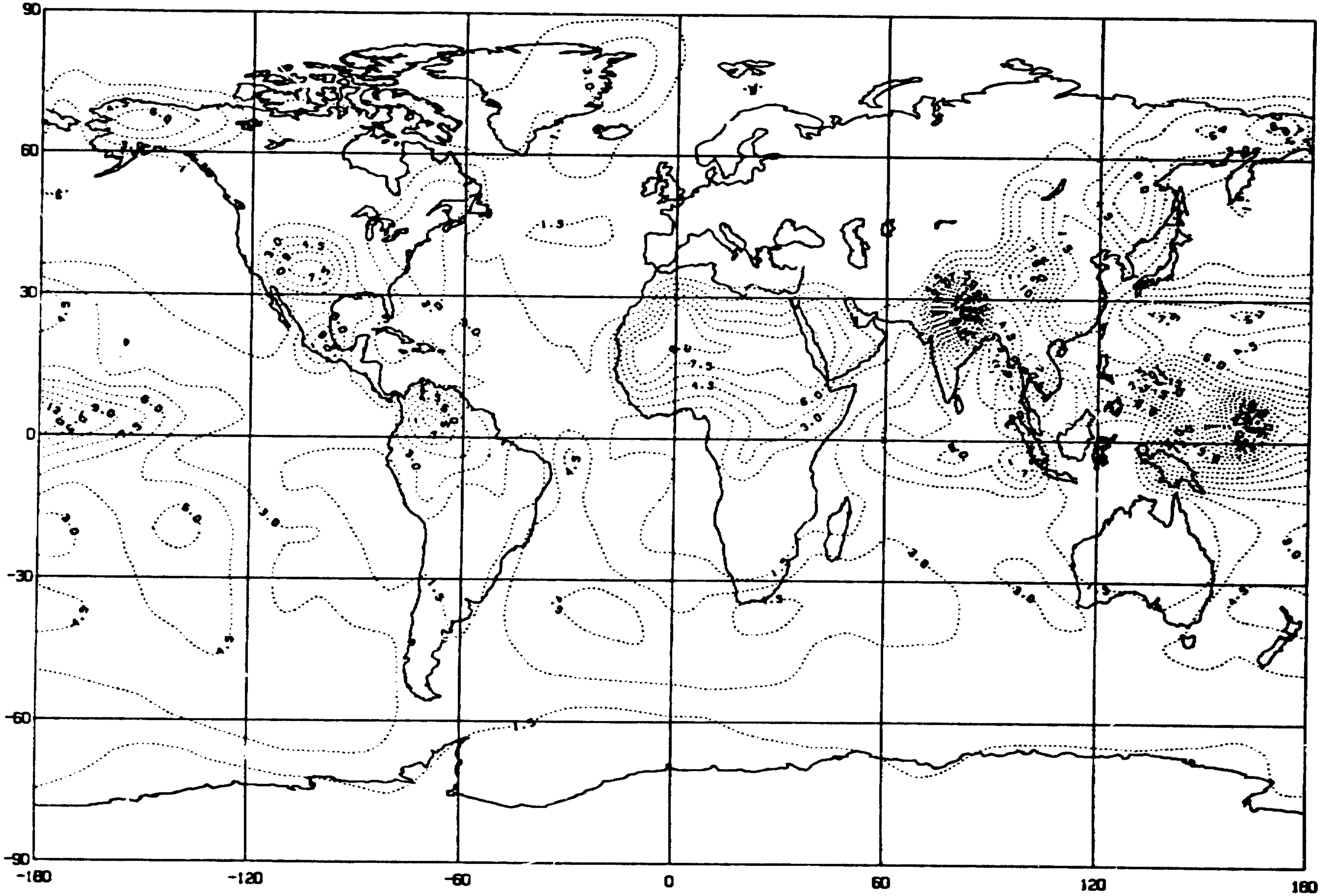

Fig. 4

MEAN PRECIPITATION. IN MM PER DAY

THE AVERAGE OF THE LAST 20 MONTHS OF RUN 05L

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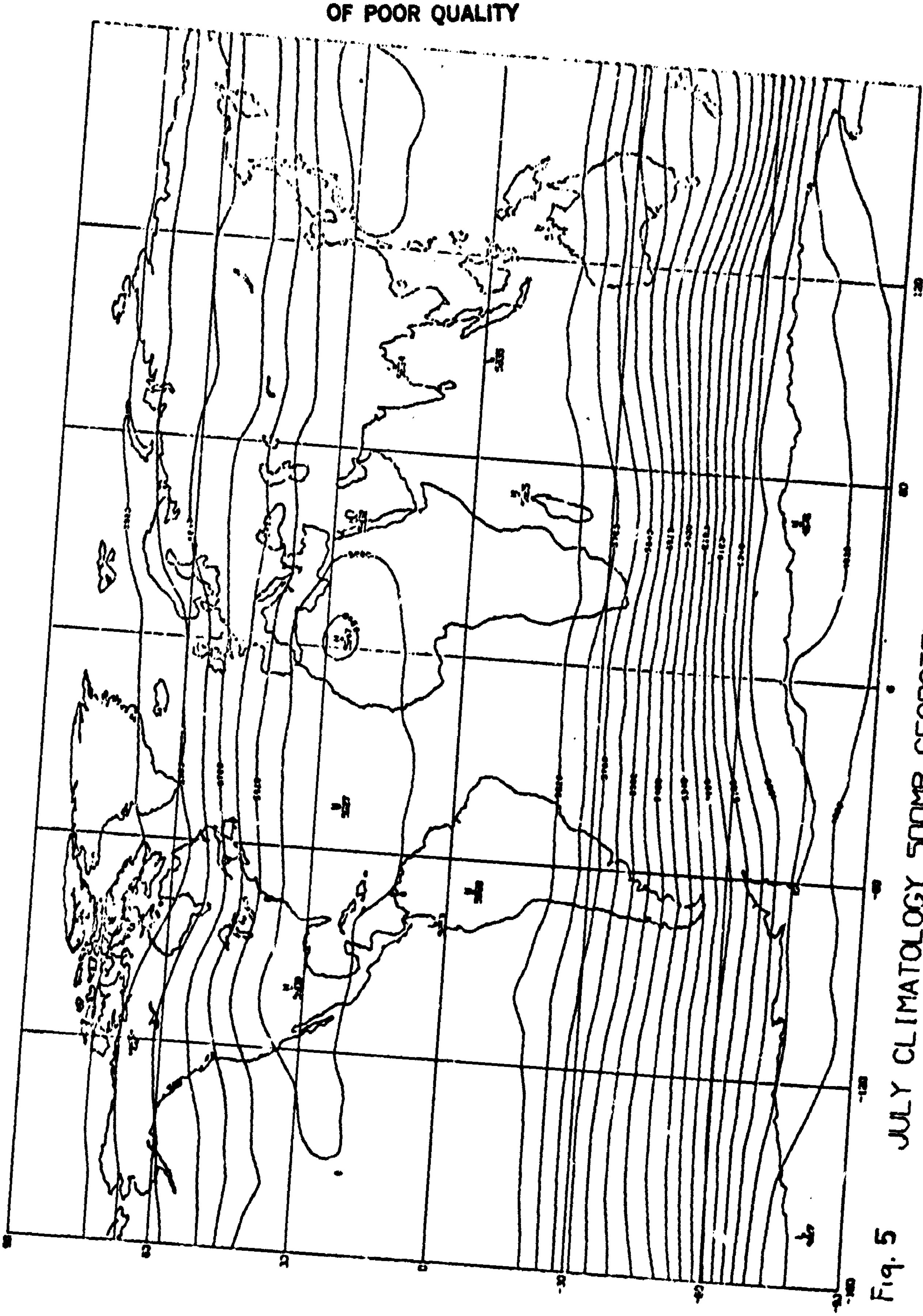

Fig. 5 JULY CLIMATOLOGY 500MB GEOPOTENTIAL HEIGHT

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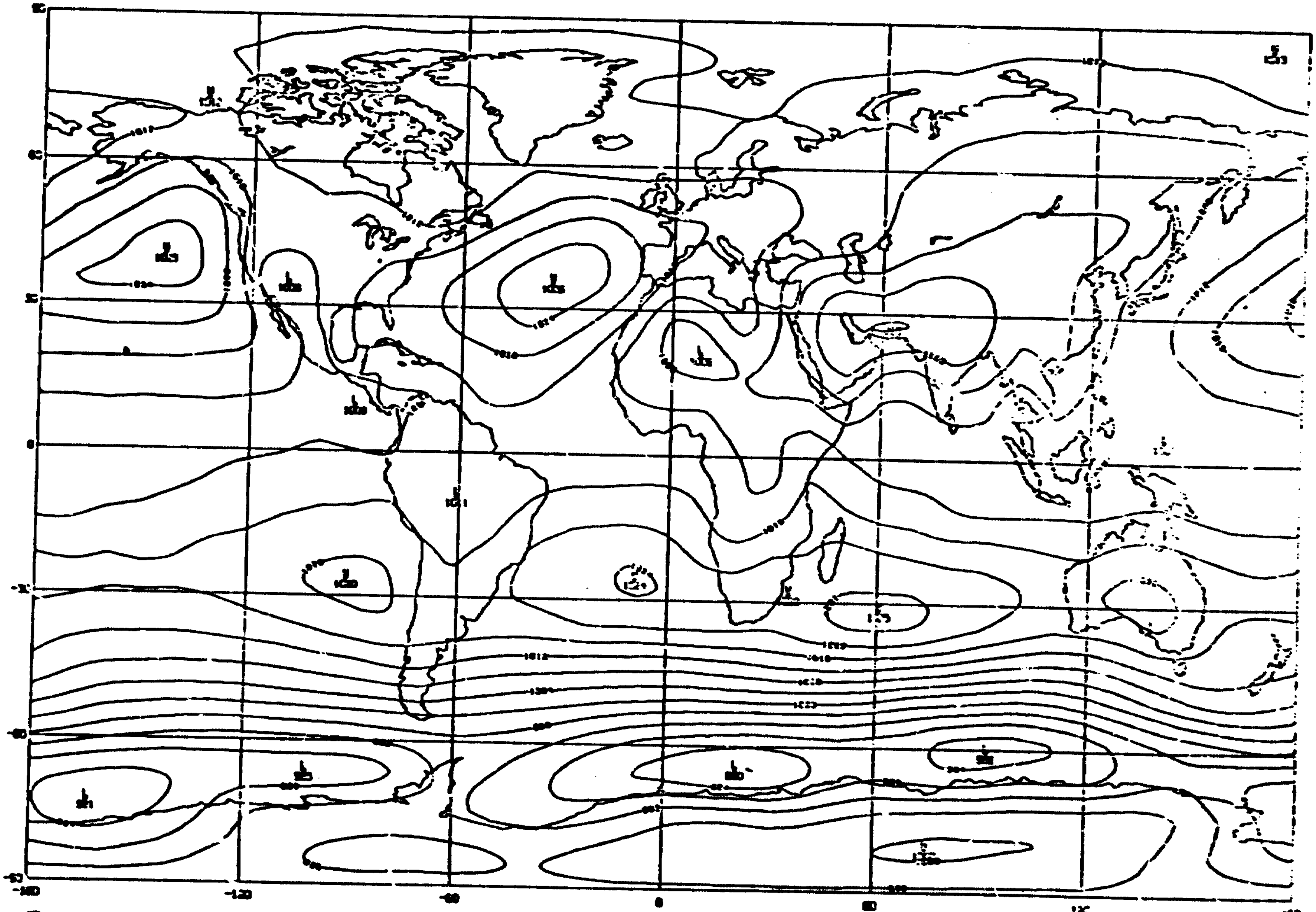


Fig. 6

JULY CLIMATOLOGY SEA LEVEL PRESSURE

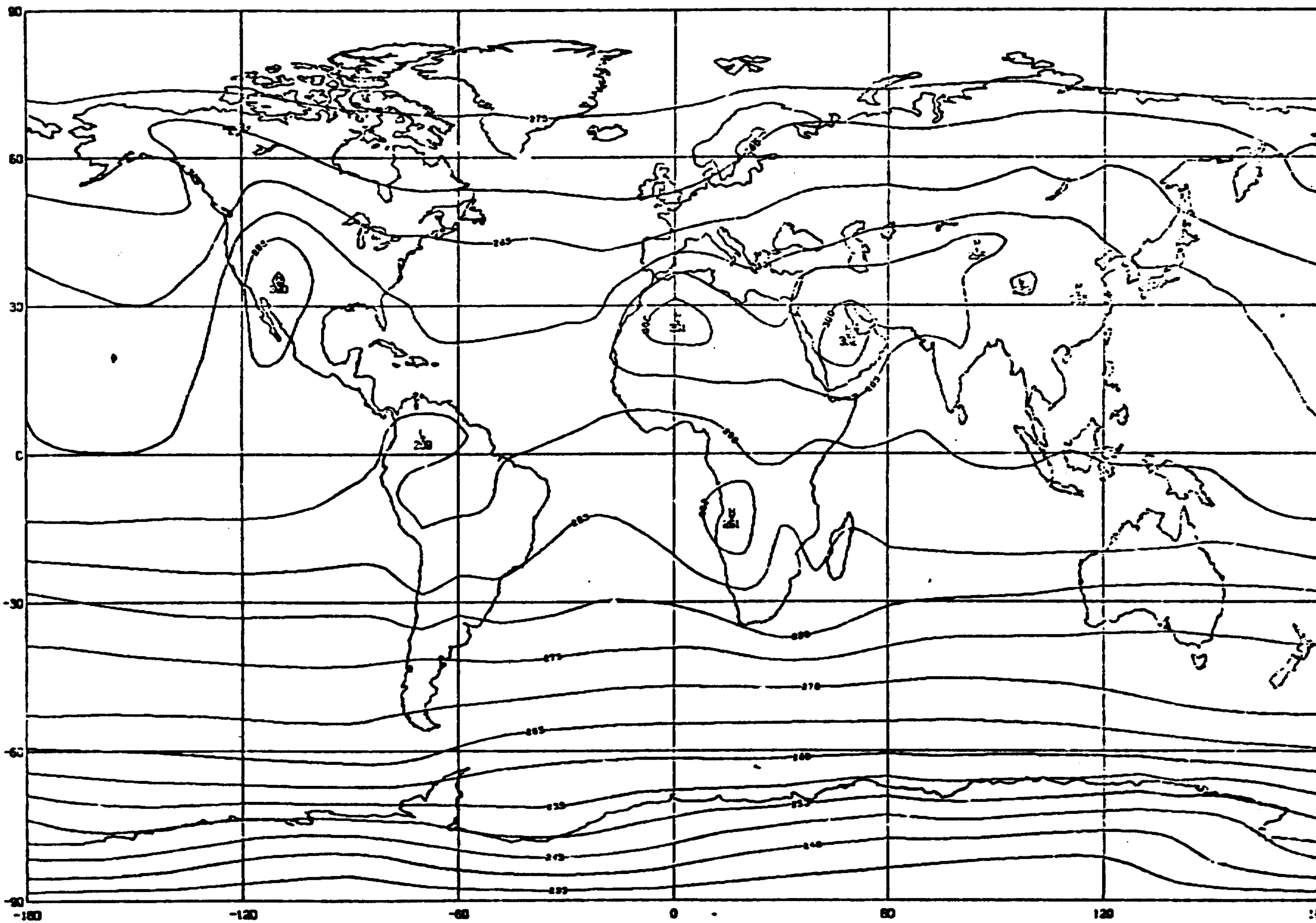


Fig. 7 JULY CLIMATOLOGY 850MB TEMPERATURE

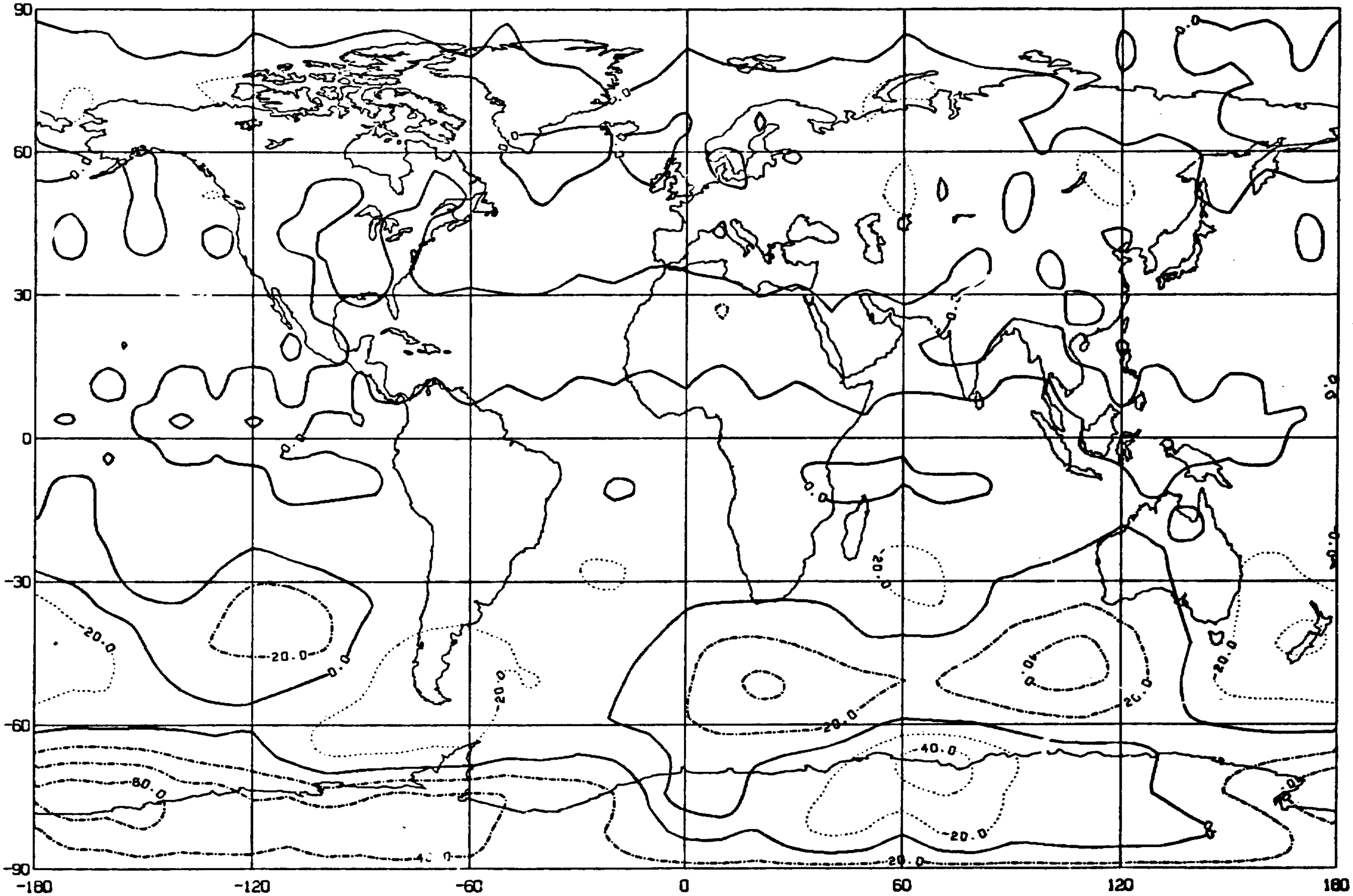
Antarctica is poorly represented in the model simulation.

The temperature field generated by the model for the 1000-850 mb layer (fig. 3) may be compared with the climatological 850 mb surface temperature (fig. 7). Allowing for the difference between the two levels examined (about 925 mb vs. 850 mb), it is seen that the model temperatures are too high over the tropical and summer continents and too low over Antarctica.

The global precipitation map (fig. 4) illustrates several deficiencies of the model-generated hydrology. The rainy belt over Africa lies too far north (over the Sahara), the maximum rainfall over North American appears over the southwestern desert rather than in the southeastern United States, and too little rain is found over Europe.

B. Constant albedo simulation (run 6)

The effects of variable continental surface albedo on the climate simulation may be evaluated by computing the differences of run 5 - minus - run 6, as illustrated in figs. 8-11. From figs. 8-10, it is apparent that the effect of the surface albedo on the mass and temperature fields are trivial. However, from fig. 11, there appear to be significant influences of albedo on precipitation, notably in South America, north Africa, and southeast Asia. In Africa, the use of variable albedo reduces the unrealistically high rainfall over the Sahara, but does not improve the location of the maximum, while in northwestern South America, use of variable albedo further exaggerates the magnitude of the maximum. However, it is the monsoonal rainfall of India, southeast Asia, and Indonesia that appears to be most significantly affected by the geographical variations of surface albedo.



500 mb Geopotential height in (meters)

The Difference of RUN05L-RUN06L

Fig. 8

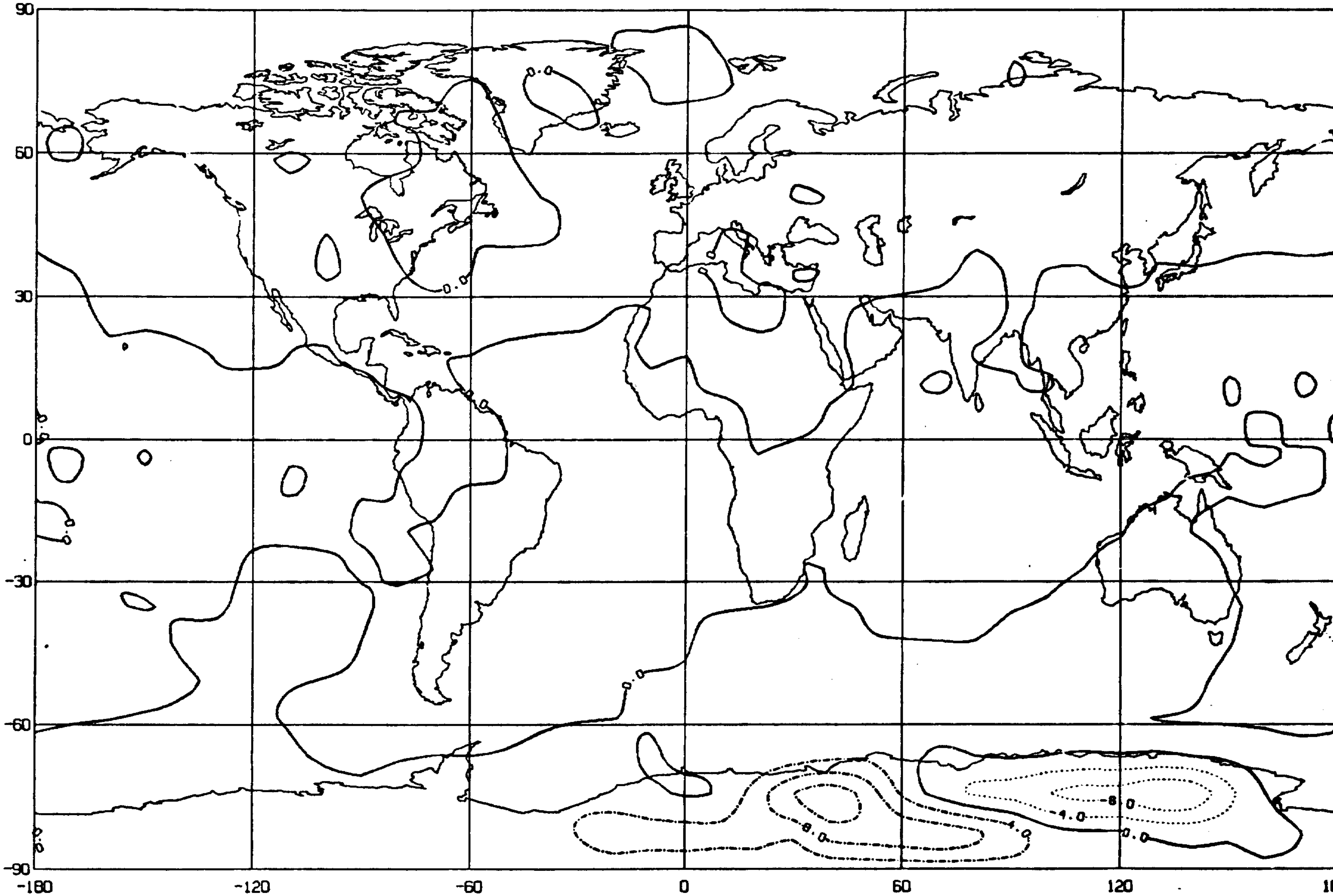
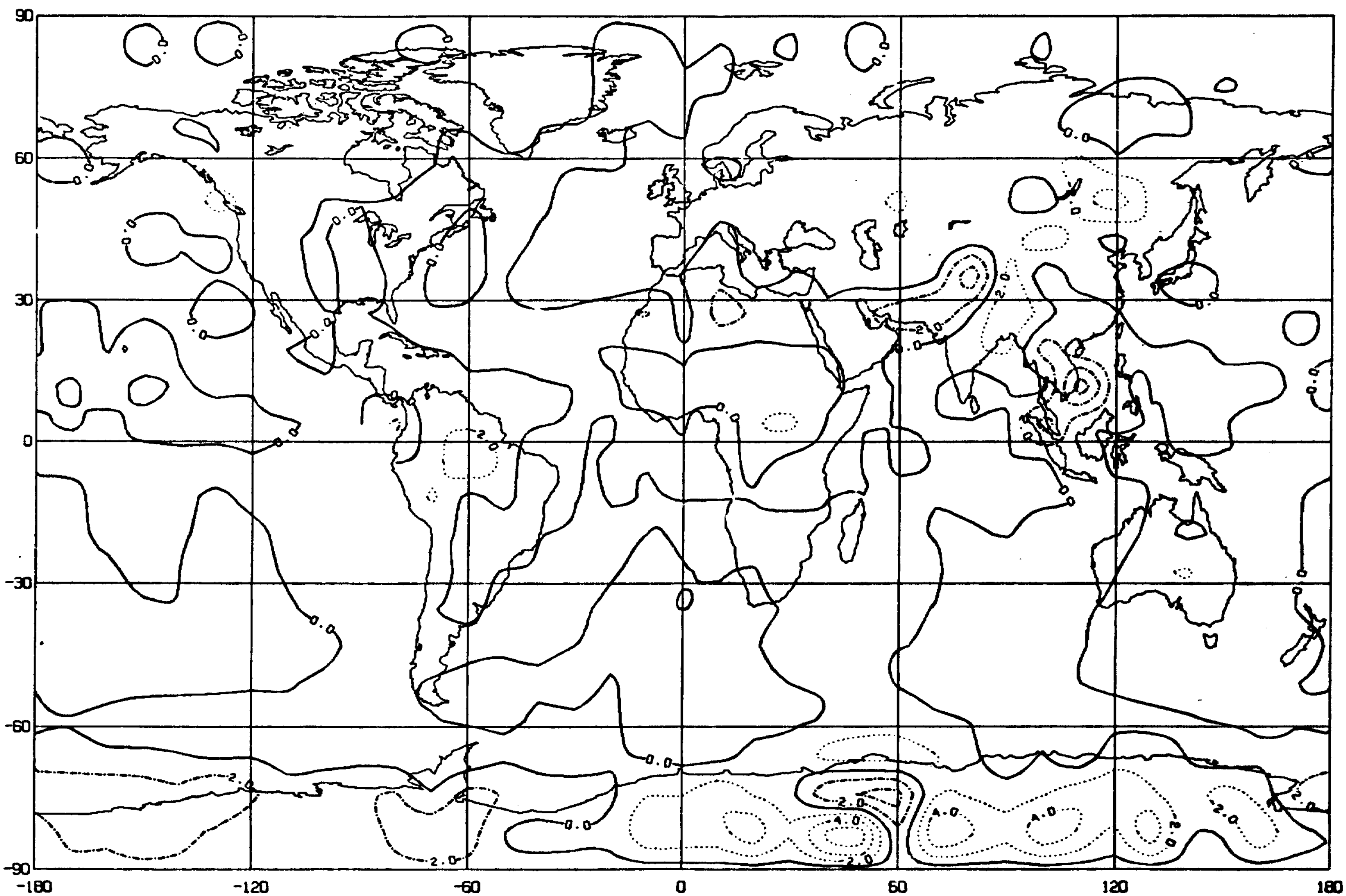


Fig. 9 *Sea level pressure in (millibars)*

The Difference of RUN05L-RUN06L



Thickness Temperature from 850 mb to 1000 mb in degree k

The Difference of RUN05L-RUN06L

Fig. 10

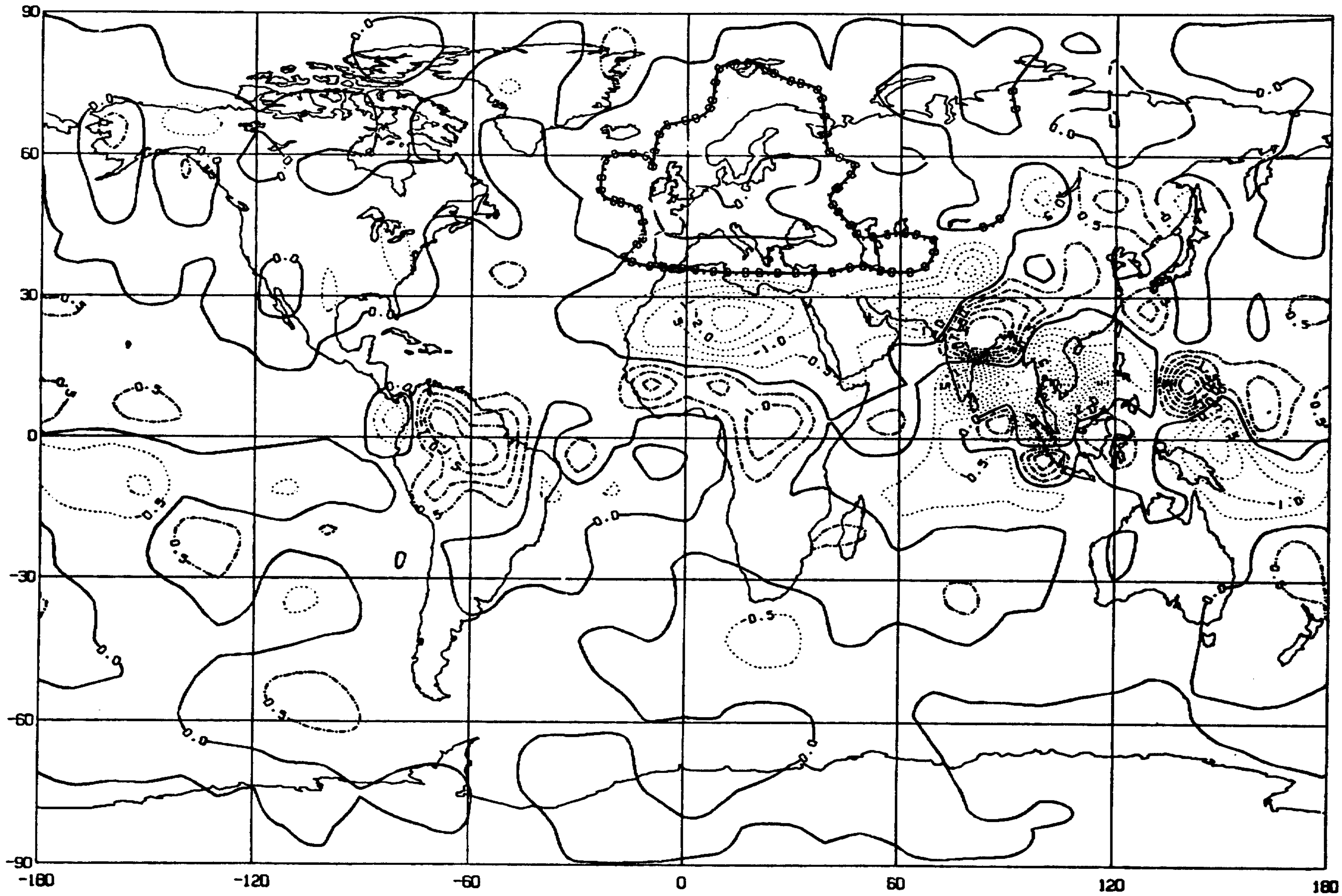


Fig. 11 *Precipitation in millimeters per day*

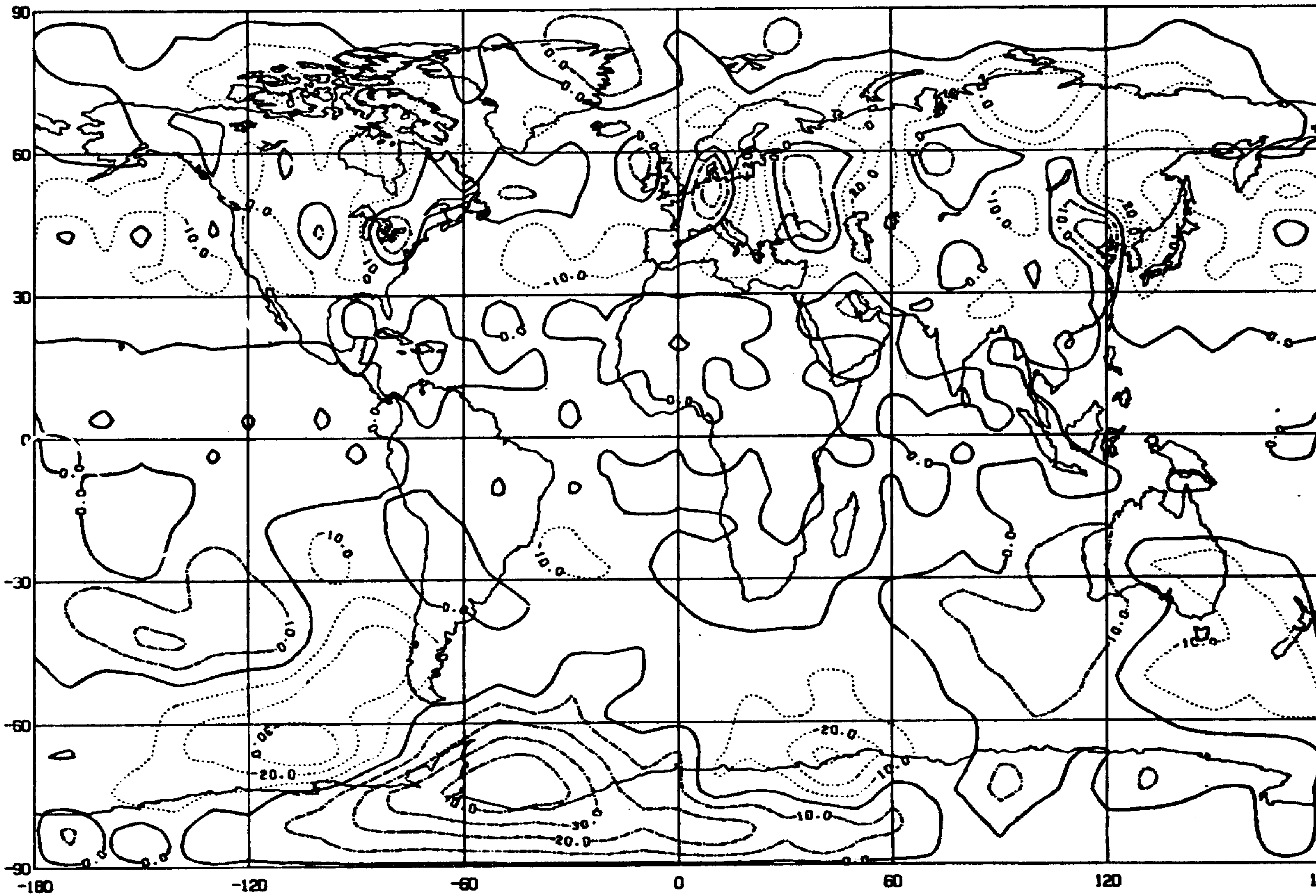
The Difference of RUN05L, RN06L

C. Dry continent simulation (run 7)

The influence of soil moisture on the model July climatology may be assessed from the differences between the means of run 5 and run 7, as illustrated in figs. 12-15. From figs. 12 and 13, it appears that the effect of soil moisture on the mass field is quite small, except over Antarctica (which is rather surprising). Low level temperature effects of soil moisture, illustrated in fig. 14, are found not only in Antarctica, but also over North America, Europe and Asia. However, the most puzzling result of the experiment is the almost negligible effect of soil moisture on precipitation, as shown in fig. 15, compared with the large effect of albedo variation on precipitation shown in fig. 11. The result was quite unexpected.

D. Concluding remarks

The attempt to separate the effects of geographical albedo variations and soil moisture on the model-generated July climatology has led to the surprising result that precipitation is more strongly affected by the former than by the latter, a conclusion that may be more model-dependent than realistic. Some insight into the relative influences of these two surface boundary conditions may gleaned from an examination of the surface temperature effects of albedo variations and soil moisture, which are illustrated in figs. 16 and 17, respectively. It is apparent that soil moisture has a trivial effect on surface temperature in the model simulation, while albedo variations have a strong effect, contrary to the effects on the 1000-850 mb layer temperatures. If the precipitation generated by the model is largely convective, the stability effect resulting from the surface temperature modification will be dominant, and the precipitation will be more strongly influenced by albedo variations than by soil moisture.



500 mb Geopotential height in (meters)

The Difference of RUN05L, RUN07L

Fig. 12

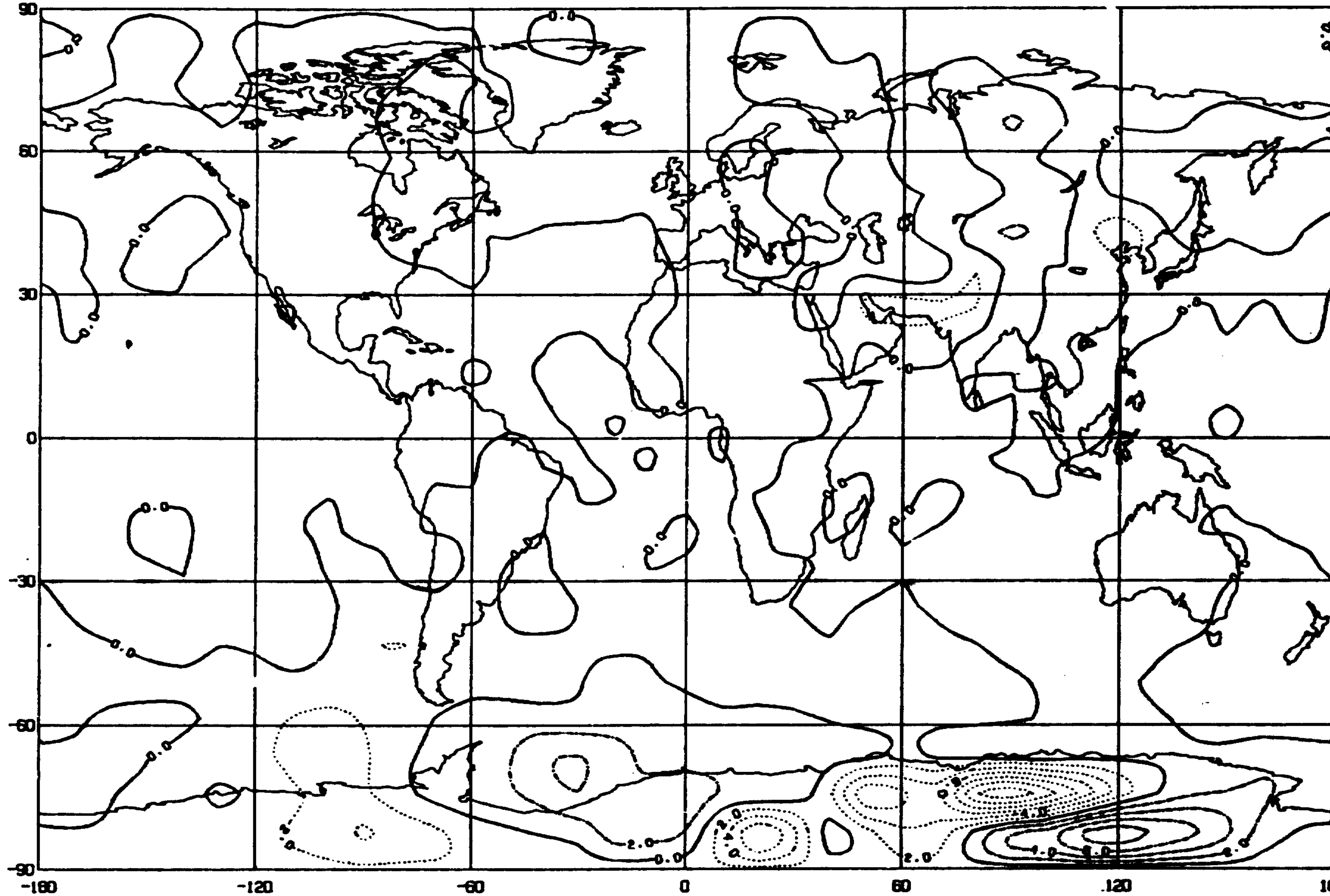
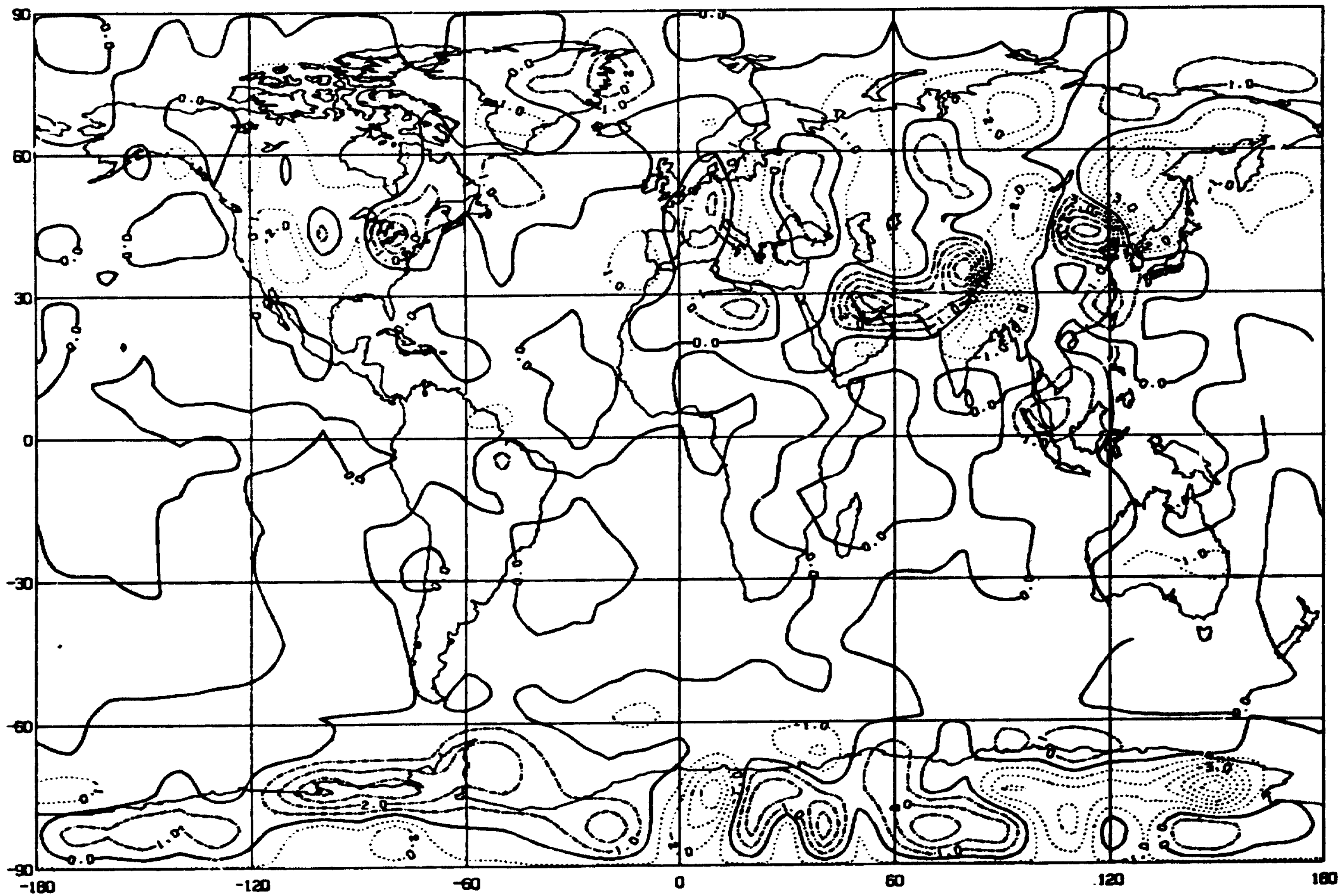


Fig. 13 *Sea level pressure* *in (millibars)*

The Difference of RUN05L, RUN07L



Thickness Temperature from 850 mb to 1000 mb in degree k

The Difference of RUN05L, RUN07L

Fig. 14

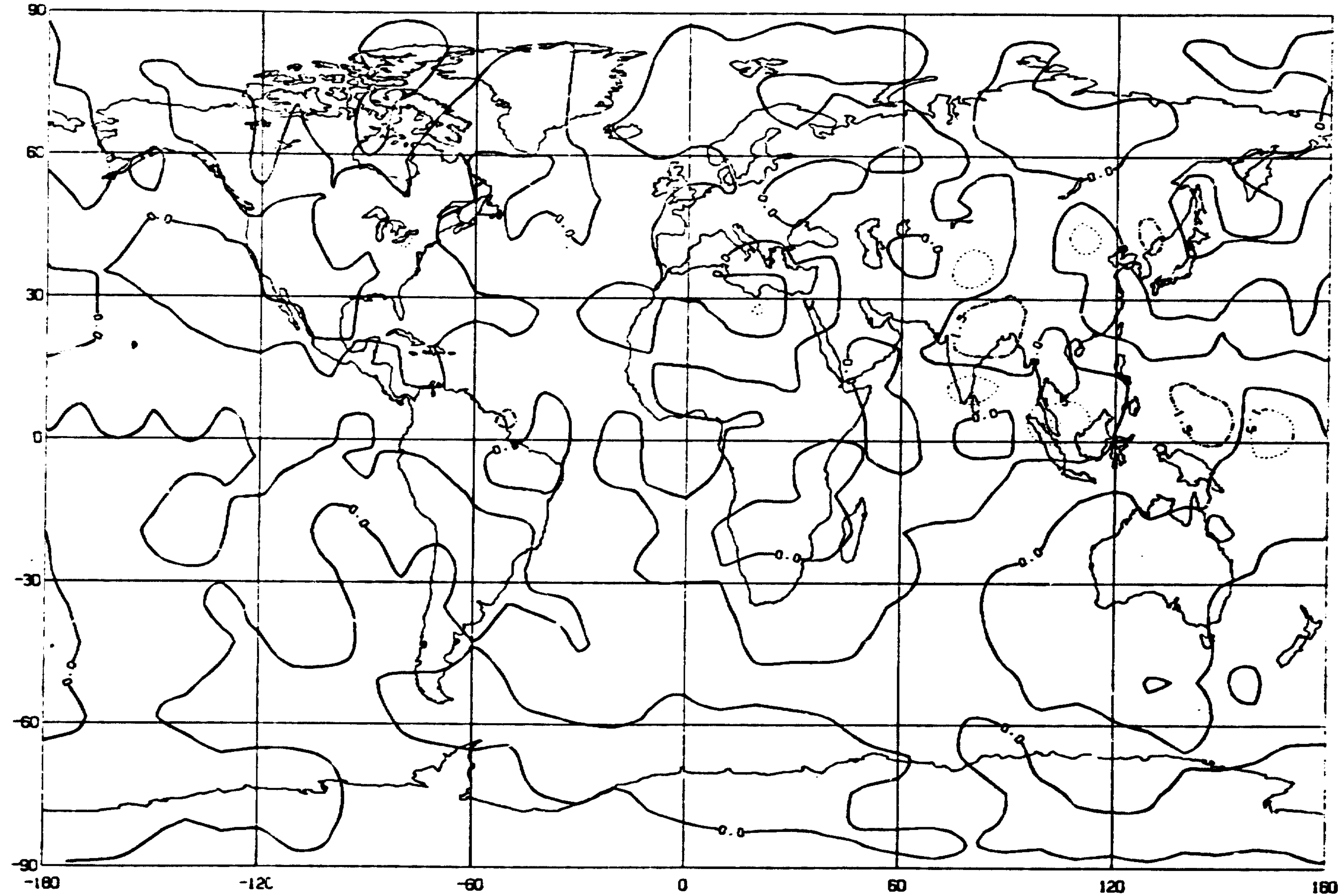


Fig. 15

Precipitation in millimeters per day

The Difference of RUN05L, RUN07L

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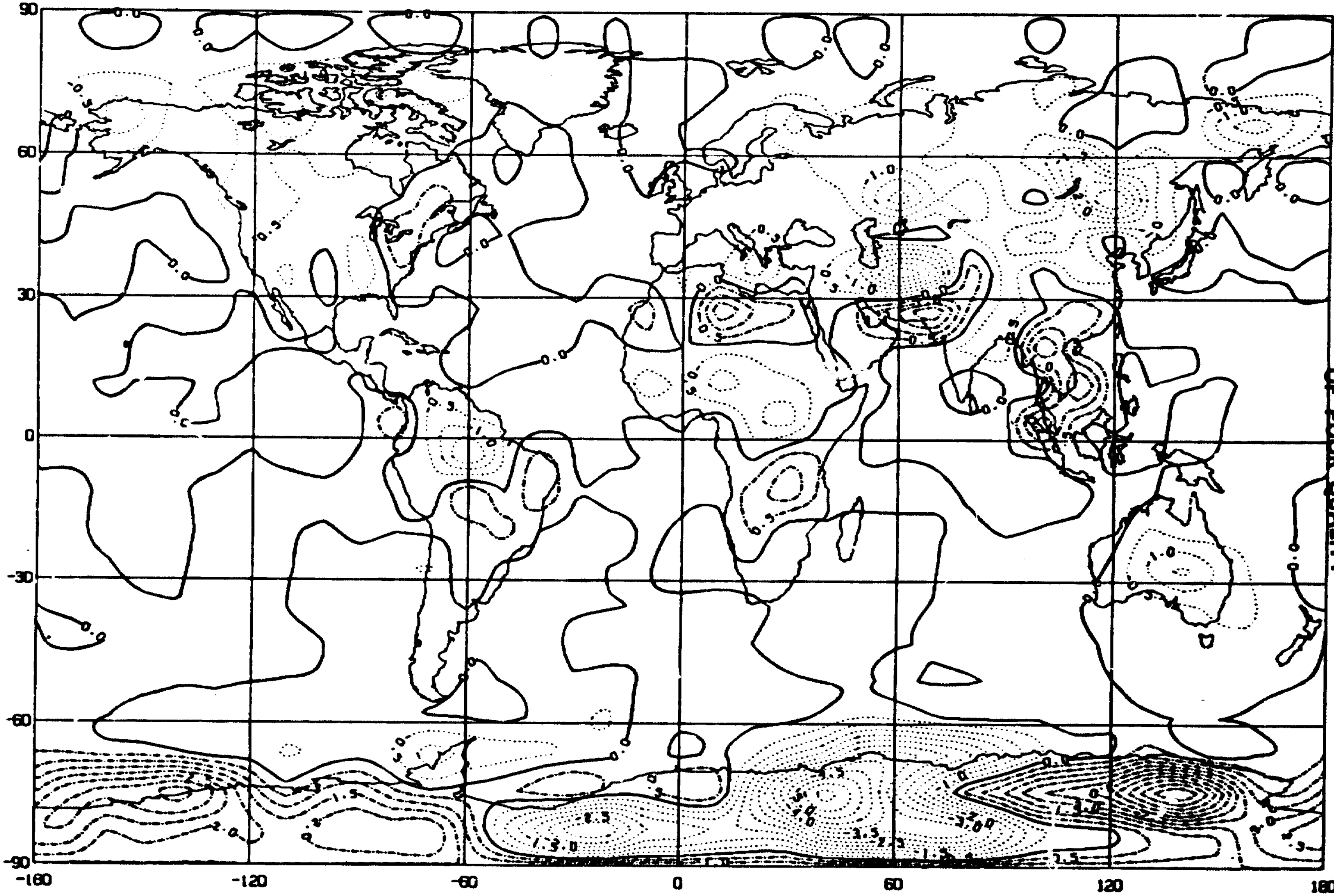

Fig. 16

Surface temperatures in degrees C

The Difference of RUN05L-RUN06L

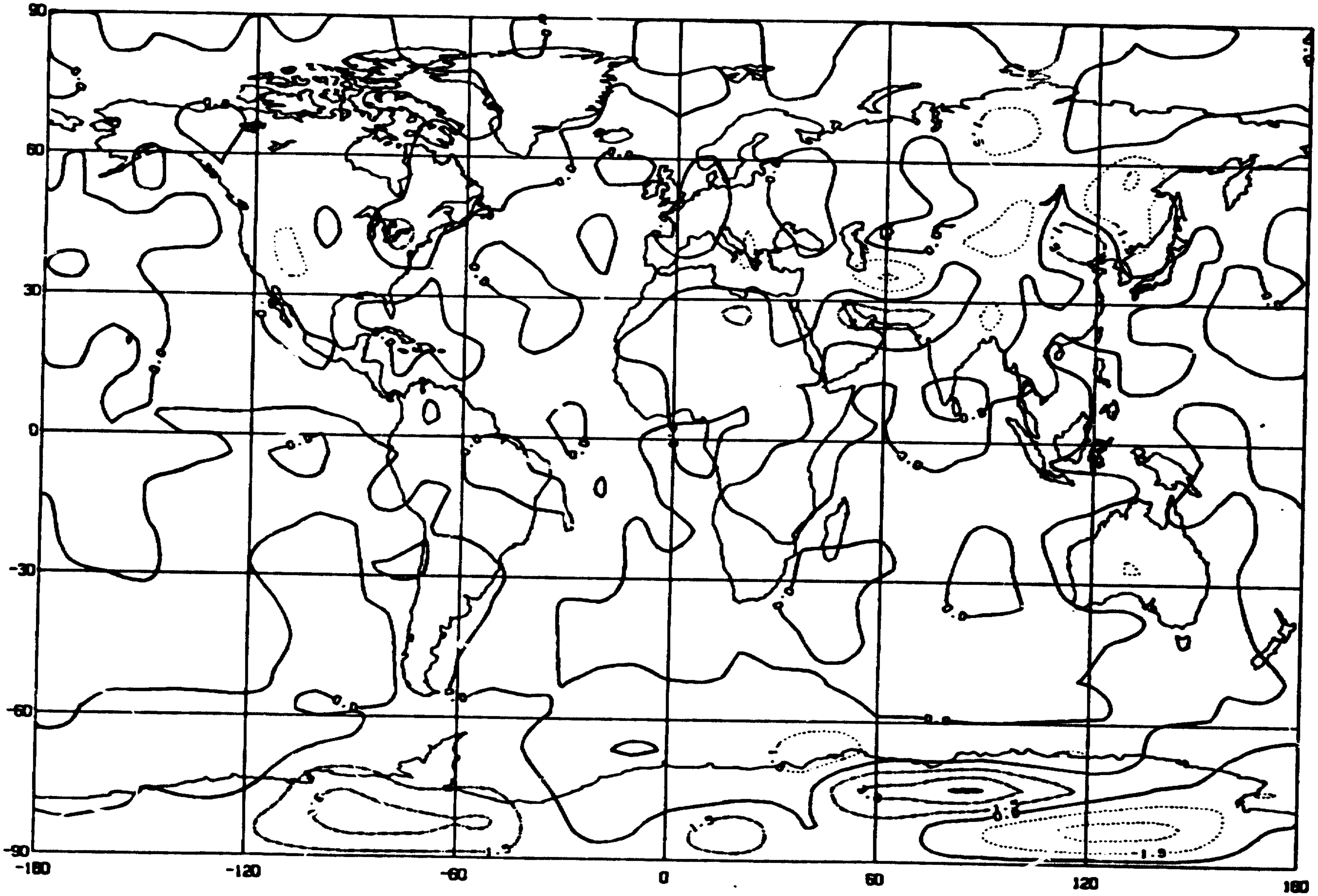

Fig. 17

Surface temperatures in degrees C

The Difference of RUN05L, RUN07L

This appears to have been the case in this calculation, with the stability effect dominating over the effect of the moisture added by continental evaporation

References

Cohen, C., 1981: The effect of surface boundary conditions on the climate generated by a coarse-mesh general circulation model. Technical Report, Grant NGR 33-013-086, NASA, Goddard Space Flight Center. The City College, N. Y., N. Y. 10031.

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